Department of Civil & Environmental Engineering
THE UNIVERSITY OF UTAH

WASP Modeling for Utah Lake

Basic Theory, Parameters, System Variables, Calibration/Sensitivity Analyses

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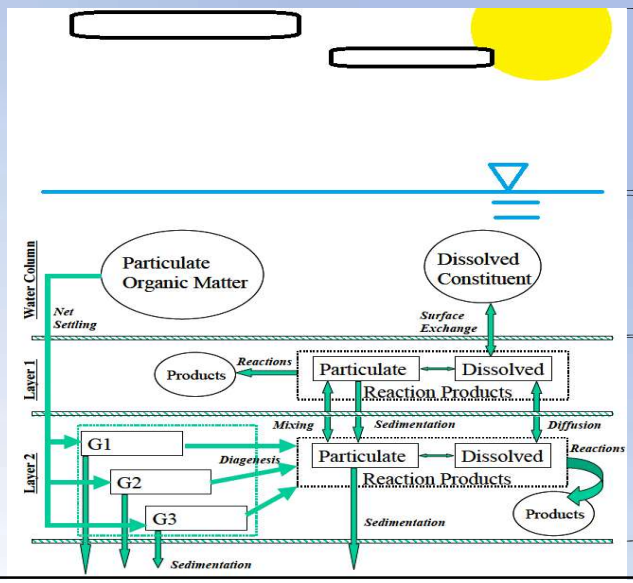
Basic Structure of WASP Segment



Atmospheric Processes

Atmospheric-Water Column Processes

Sediment-Water Column Processes

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General Descriptions of Processes

- **Atmospheric Processes** describe the contribution of lighting and heat into the water column.
- **Water Column Processes** incorporate the contribution from the atmosphere (lighting, heat, etc.) and from the sediment at the bottom layer, which are combined with the aqueous chemical/biological processes for different constituents of interest.
- **Sediment Processes** describe the contribution of the particulate constituents from the sediment layer into the water column.

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General Descriptions of Processes (continued)

- **Atmospheric Processes** (Lighting, Heat, Aeration (Gas-Liquid))
- **Water Column Processes** (Flow among Nodes/Segments, Exchanges (e.g., Dispersion), Chemical/Biological Reactions (Nitrification, Denitrification, Reaeration, Photosynthetic Processes from Lighting in Atmosphere, etc.), Macro/Benthic Algae Contributions, etc.)
- **Sediment Processes** (Sediment Diagenesis Routines, Benthic Nutrient Fluxes)

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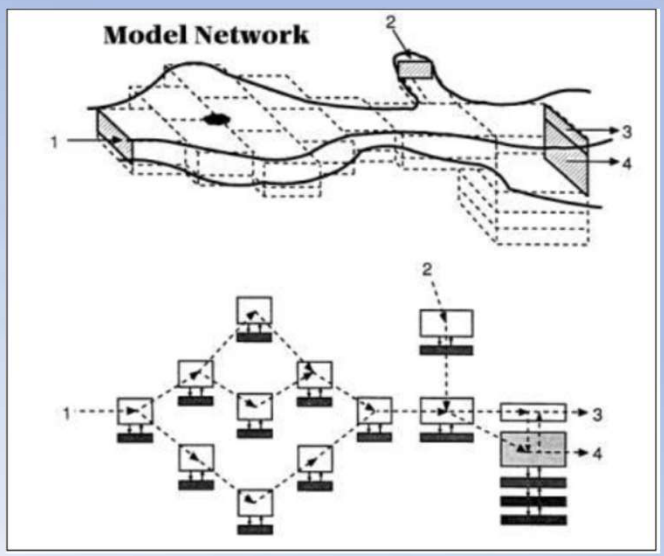
Model/Nodes Setup in WASP



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Model/Node Setup in WASP

- "Boxed" Model
- Flows as **Inputs** into WASP
  - Uni-directional flow only in WASP
  - Hydrodynamic Linkage Required for Lakes/Reservoirs
  - Hydrologic Processes NOT included/simulated in WASP
  - Precipitation/Evaporation Processes as <u>inputs</u> but only impact **flows** into model
  - Mass Constituent Loadings (Mass Rates) and Sources (e.g., WWTP sources) as **inputs** into model

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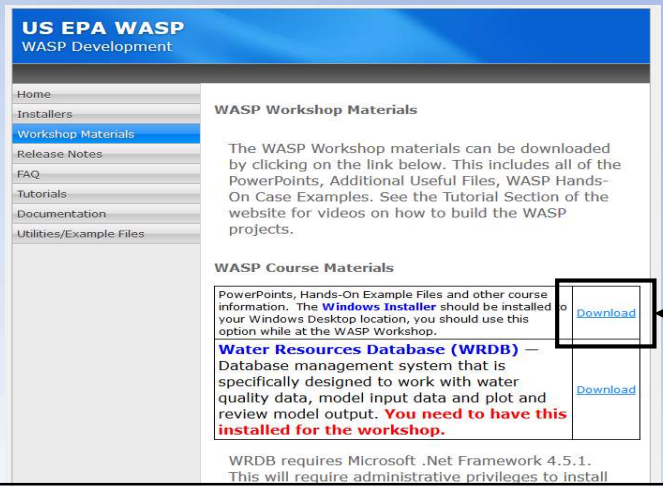
Supplementary WASP Materials

- Website for Presentations: http://epawasp.twool.com/workshop/



Several Presentations over different characteristics, model setup, processes, and constituents of WASP 8.2

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Supplementary WASP Materials (continued)

- Website for User Manuals: http://epawasp.twool.com/docs/
- Website for Tutorials: http://epawasp.twool.com/tutorials/
- Website for Installers: http://epawasp.twool.com/installers/ (Open-Source)

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Constituents/System Variables for Utah Lake WASP

General Model Description, System Variables/Constituents Simulated

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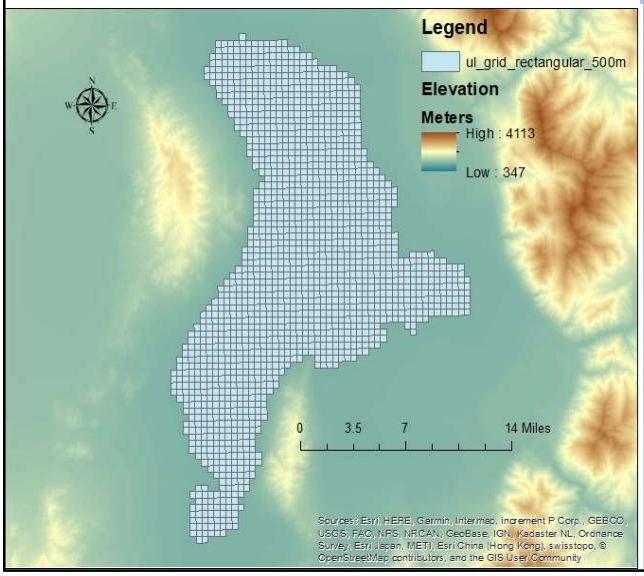
Utah Lake Model



- Approximately **1650 Water Columns**
- EFDC Hydrodynamic Linkage
- 3-5 Layers for each water column
- **11 inflows**
  - Provo River
  - American Fork River
  - Timpanogos WWTP
  - Lindon Drain
  - Powell Slough
  - Mill Race
  - Dry Creek
  - Spanish Fork River
  - Benjamin Slough
  - Hobble Creek
- **1 outflow** (Jordan River)

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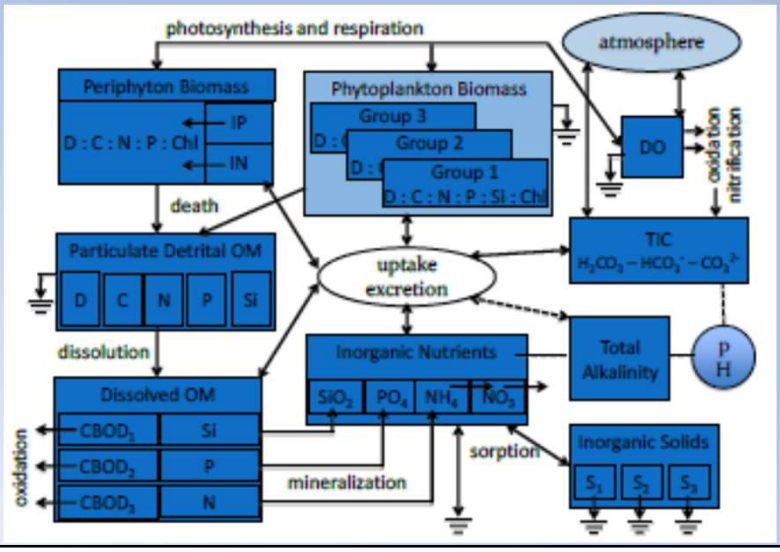
Flow Chart for WASP Constituents (The Advanced Eutrophication Model)



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Constituents for Utah Lake WASP- The "Basics"

- **Water Temperature**
- **pH**
- **Alkalinity**
- **Total Dissolved Solids (Freshwater)**

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Constituents for Utah Lake WASP- Nutrients

- **Nitrogen Species:** Ammonia-Nitrogen, Inorganic Nitrogen (Nitrate and Nitrite), Organic Nitrogen (Dissolved and Particulate)
- **Phosphorus Species:** Dissolved Inorganic Phosphate, Organic Phosphate (Dissolved and Particulate)
- **Carbonaceous Biochemical Oxygen Demand (CBOD):** up to **5 ultimate CBOD groups**
- **Phytoplankton:** up to 5 groups
- **Dissolved Oxygen**
- **Macro Algae:** Chlorophyll-a, Nitrogen, Phosphorus Components; up to **5 groups** for Macro Algae; can be Benthic (not transported) or Macro (transported) Algae for each group

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Constituents for Utah Lake WASP- Sediments

- **Particulate Organic Matter (POM)/Total Detritus**
  - **Particulate Organic Carbon (POC)/Detrital Carbon**
  - **Particulate Organic Nitrogen (PON)/Detrital Nitrogen**
  - **Particulate Organic Phosphate (POP)/Detrital Phosphate**
  - **Note:** 1 group allowed for each of POC, PON, POP, and POM
- **Inorganic Suspended Solids (TSS):** up to **5 groups** allowed in WASP; sediment/solids transport optional but NOT recommended for WASP

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Input Parameters

Environmental Time Functions, Segment/Node Characteristics, Sources and Loadings, Meteorological/Chemical/Biological Constants

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Notes for the Following Slides on Input Parameters

1. Only the "**significant**" parameters are included. ALL parameters listed are eligible to be **calibrated** against the measured data.
2. A parameter that is indicated with "*" means that the parameter can be simulated as an output in WASP (e.g., the **sediment diagenesis routine**).
3. A parameter that is indicated with "+ (value)" means that the parameter may exhibit a **"typical" value** other than a default value assigned by WASP, based upon the **Jordan River Qual2K Model (Utah Division of Water Quality 2009)**. Sensitivity/Calibration approaches for some to significant amount of these parameters will be implemented based upon such typical values assigned.
4. All decay, mineralization, and chemical rates correspond to those at **20 degrees C**.

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Atmospheric Processes

- **Meteorological Time Functions (up to 4 sets of time series each)**
  - Air Temperature (Celsius)
  - Dewpoint Temperature (Celsius)
  - Wind Speed (Meters/Second)
  - Solar Radiation (W/m^2)
  - Cloud Cover (Fraction)
- **Lighting Constants (apply to <u>entire model</u>):**
  - Surface/Water Albedo
  - Detritus and Inorganic Solids Lighting Constant (1/m)
  - Light Fraction as Photosynthetically Active Radiation (PAR)
  - Background Light Extinction (1/m)
  - DOC Light Extinction Constant (1/m) (can be applied for each CBOD group)
  - Light Constant for Macro/Benthic Algae Growth (Langley/Day)
  - Phytoplankton (per group) Optimal Light Sat as PAR (W/m^2)

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For the "Basic Constituents"

- **Water Temperature:** Coefficient of Bottom-Heat Exchange (W/m2-Celsius), Sediment Ground Temperature (Celsius)

  Water Temperature Model from Wool, Ambrose, and Martin "WASP8 Temperature Model Theory and User's Guide"

$$H_n = \underbrace{H_S + H_A}_{\text{Computed based upon Solar Radiation}} + H_E + H_C - \underbrace{(H_{SR} + H_{AR} + H_{BR})}_{\text{Solar Radiation Terms}}$$

- **pH and Alkalinity:** Atmospheric Pressure for CO_2 (atm)
- **Solids (TSS):** Settling Velocity (m/day) (applied to each node)

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Nitrogen Species

- **Inorganic Nitrogen (Ammonia-Nitrogen, Nitrate and Nitrite Nitrogen)**
  - Nitrification Rate at 20 degrees Celsius (1/day) + (2)
  - Nitrification Temperature Correction Coefficient + (1.07)
  - Ammonia-Nitrogen Benthic Flux (mg/m^2day)*
  - Denitrification Rate (1/day) + (0.05)
  - Denitrification Temperature Correction Coefficient + (1.07)
- **Dissolved Organic Nitrogen**
  - Mineralization Rate (1/day) + (0.4)
  - Mineralization Rate Temperature Coefficient + (1.07)

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Phosphorus Species and CBOD

- **Dissolved Inorganic Phosphate**
  - Inorganic Phosphate Benthic Flux (mg/m^2day)*
- **Dissolved Organic Phosphate**
  - Mineralization Rate (1/day) + (0.05)
  - Mineralization Rate Temperature Coefficient + (1.07)
- **CBOD (For Each Group; up to 5 Groups allowed)**
  - Decay Rate (1/day)
  - Decay Rate Temperature Coefficient + (1.07)
  - Fraction of Detritus (POM) Dissolution to CBOD
  - Fraction of CBOD Carbon Source for Denitrification

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Dissolved Oxygen and Detritus (POM)

- **Dissolved Oxygen (DO)**
  - Elevation of Node from sea level (m); for DO Saturation
  - Temperature Correction for Reaeration + (1.024)
  - Sediment Oxygen Demand ($g/m^2 day$)*
  - Temperature Correction for Sediment Oxygen Demand (SOD) + (1.07)
  - Macro Algae O2:C Production ($mg\ O_2$/mg C)
- **Detritus (POM)**
  - Dissolution Rate (1/day) + (0.1)
  - Temperature Correction for Dissolution + (1.07)
  - Settling Velocity (m/day) + (0.1)

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Phytoplankton

- **General Rates and Temperature Correction Coefficients**
  - Maximum Growth Rate (1/day)
  - Growth Temperature Coefficient
  - Respiration Rate (1/day)
  - Respiration Rate Temperature Coefficient
  - Death Rate (Non-zoo predation) (1/day)
  - Settling Velocity (m/day) (can be applied to each node)
- **Stoichiometric Ratios**
  - Detritus to Carbon (mg Dry Weight/mg C)
  - Nitrogen to Carbon (mg N/mg C)
  - Phosphorus to Carbon (mg P/mg C)
  - Chlorophyll-a to Carbon (mg C/mg Chlorophyll-a)

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Phytoplankton (continued)

- **Fraction Respiration per Group**
  - Fraction Recycled to Organic N
  - Fraction Recycled to Organic P
- **Fraction Death per Group**
  - Fraction Recycled to PON
  - Fraction Recycled to POP

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Macro/Benthic Algae

- **Fractions**
  - Fraction of each bottom node covered by benthic algae (if NOT transported)
  - Fraction recycled to Organic N
  - Fraction recycled to Organic P
- **Kinetics**
  - Max Growth Rate (g Dry Weight/m2-day for 0^{th} order; 1/day for 1^{st} order)
  - Respiration Rate (1/day)
  - Death Rate (1/day)
  - Several others…
- **Stoichiometric Ratios**
  - Phosphorus to Carbon (mg P/mg C)
  - Chlorophyll-a to Carbon (mg Chlorophyll-a/mg C)
  - Nitrogen to Carbon (mg N/mg C)
  - Detritus/POM to Carbon (mg Dry Weight/mg C)

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Half-Saturation Constants

- **Nitrogen Species:** Nitrification Half-Sat Oxygen Limit (mg O2/L), Denitrification Half-Sat Oxygen Limit (mg O2/L)
- **CBOD (for each group):** CBOD Half-Sat Oxygen Limit (mg O2/L)
- **Phytoplankton (for each group):** Half-Sat for Mineralization (mg Phytoplankton C/L), Half-Sat for N Uptake (mg N/L), Half-Sat for P Uptake (mg P/L)
- **Macro/Benthic Algae:** Half-Sat Uptake Constant for Extracellular N (mg N/L), Half-Sat Uptake Constant for Extracellular P (mg P/L), Half-Sat Uptake for Intracellular N (mg N/L), Half-Sat Update for Intracellular P (mg P/L)

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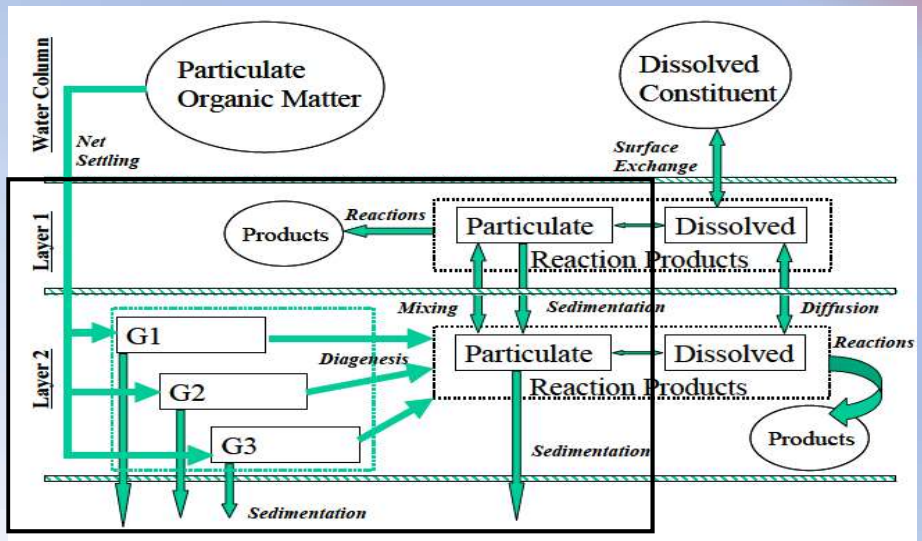
Sediment Diagenesis



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Sediment Diagenesis Parameters

- **Initial Concentrations in Each Node**
  - Particulate Organic Carbon (POC)/Detrital Carbon (mg/L)
  - Particulate Organic Nitrogen (PON)/Detrital Nitrogen (mg/L)
  - Particulate Organic Phosphate (POP)/Detrital Phosphate (mg/L)
- **Fractions into Each G Class <u>per node (bottom nodes) with sediment diagenesis routine enabled</u> (Previous Slide)**
  - Fraction into Class G1
  - Fraction into Class G2
  - Fraction into Class G3
  - $\sum_{i=1}^{3} f_{G,i} = 1$
- **Sediment Diagenesis Segmentation (User-Defined)**
- Several others under Martin and Wool (2017) "WASP Sediment Diagenesis Routines: Model Theory and User's Guide", in WASP "Constants" ➔ "Sediment Diagenesis"

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General Information over Input Parameters

- Default Values used if no values are specified by user for all parameters except <u>meteorological time functions</u>
- Requires a **calibrated EFDC hydrodynamic model** (particularly **water depth**)
- Some to several parameters to-be-provided by Dr. Ramesh Goel's Research Group for the Project (sampling/experimental analyses over Utah Lake)
- Some lighting parameters (e.g., background light extinction, etc.) possibly provided by the Utah Division of Water Quality
- Significant amount of parameters are **constant** throughout the **entire** simulation period, with only **temperature-correction coefficients** (and other model characteristics) adjusting such values.

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Sensitivity Analyses/Calibration Approaches

- **Sensitivity Analyses:** based upon increasing/decreasing values by a constant amount (e.g., by 0.5, 1.5, 2, etc.) for **some to several** of the parameters described in previous slides (due to simulation time)
- **Calibration Approaches (tentatively)**
  - Comparison with measured **AWQMS Data for selected Utah Lake sites (measured by Utah Division of Water Quality)**
  - Non-detects: Using 85% of Lower Quantification Limit (provided by AWQMS)
  - **Calibration Period:** based upon EFDC Model (anytime between Water Year 2006 to Water Year 2015)
  - **Historical Baseline Simulation:** Time Period to-be-determined based upon other models (DHSVM, SWMM, GoldSim, EFDC, and WASP for both Utah Lake and Jordan River)
  - May be based upon **visual inspection (plotting simulated vs. measured results) for the water quality constituents (Slides 12-14)**, with possible (if time permits) statistical analyses (e.g., MSE) depending on measured data quality

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Jordan River and Utah Lake at Different Times

A significant amount of Input Parameters in WASP are constant throughout the ENTIRE simulation period.

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February 27, 2018

Part of Jordan River

Part of Utah Lake

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June 12, 2018

Part of Jordan River

Part of Utah Lake

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August 3, 2018

Part of Jordan River

Part of Utah Lake

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Questions?

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